

IMPLEMENTING A MODERN MATHEMATICS PROGRAM  
IN THE SECONDARY SCHOOLS

by

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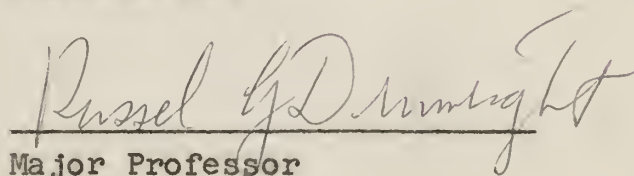
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## INTRODUCTION

Many studies have reported that proper mathematical instruction in secondary schools is of utmost importance in the scientific and technical education of our young people, and that the present curriculum is badly adapted to the needs of our students. Recent developments in mathematics itself, the importance of mathematics in general education, and the shifting needs of science and technology now require many portions of elementary mathematics to be revised and the replacement of certain topics with others which are now considered of greater importance. Since many types of programs have met with success, it seemed important to consider the different aspects of implementing a modern mathematics program in the secondary school.

### Statement of the Problem

It was the purpose of this study (1) to show why curricular revision in mathematics is necessary; (2) to determine what form this revision should take; and (3) to present the steps in implementing a new program of modern mathematics in the secondary schools.

### Limits of the Study

Research on this problem included a review of all available literature regarding this topic. Study and consideration were given to reports concerning experimental

research with modern mathematics curriculums rather than a review of commercial texts. This study was also limited to secondary schools which consisted of grades seven through twelve.

### Method of Procedure

The method of carrying out this investigation of modernizing a mathematics curriculum was reading and library research. All available literature, books, periodicals and encyclopedias in the main library at Kansas State University were investigated.

## DEFINITIONS OF TERMS USED

### Mathematics Curriculum

The mathematics curriculum in this report was interpreted as including the following subject: seventh and eight grade mathematics, algebra one and two, general mathematics, geometry and advanced mathematics which usually includes an introduction to calculus and analytic geometry, trigonometry and other selected topics.

### Secondary Schools

Throughout this report the term secondary schools was defined as an educational program for those students in grades seven through twelve. This included students in grades seven through twelve in the eight-four, six-six, and

six-two-six school systems.

### Modern Mathematics

The term modern mathematics was used throughout this report. Modern mathematics was considered as both a point of view and new subject matter. The new point of view was attained by looking at the content of elementary mathematics in the light of the new subject matter. There is no sharp dividing line between traditional mathematics and modern mathematics. The development of mathematics has been continuous; the newer ideas have grown out of the older; and many teachers were presenting traditional content from a point of view accurately described as modern.

The Commission on Mathematics, consisting of university mathematicians, leaders in the training of teachers of mathematics and secondary school teachers, proposed a nine-point program for the college-capable students. Most modern mathematics courses in the secondary schools consist of some of these following nine points:

1. Strong preparation, both in concepts and in skills for college mathematics at the level of calculus and analytic geometry.
2. Understanding of the nature and role of deductive reasoning - in algebra, as well as in geometry.
3. Appreciation of mathematical structure (patterns) - for example, properties of natural, rational, real, and complex numbers.
4. Judicious use of unifying ideas - sets, variables, functions, and relations.



5. Treatment of inequalities along with equations.
6. Incorporation with plane geometry of some coordinate geometry, and essentials of solid geometry and space perception.
7. Introduction in grade eleven of fundamental trigonometry - centered on coordinates, vectors, and complex numbers.
8. Emphasis in grade twelve on elementary functions (polynomial, exponential, circular).
9. Recommendation of additional, alternative units for grade twelve; either introductory probability with statistical application or an introduction to modern algebra.<sup>1</sup>

Some of the changes that have taken place in these modern mathematics courses are as follows: In a modern algebra one course little change in the actual content has taken place. But modern algebra is approached from a fundamentally altered point of view. Algebra is treated as a study of inequalities, equations, and of expressions involving the concept of absolute value. The notions of sets, statements, variables, relations and functions are formulated in modern algebra. In summary, some of the trends in modern algebra one are:

1. The use of patterns.
2. Careful definitions and use of terminology.
3. The introduction of proofs.

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<sup>1</sup>Julius H. Hlavaty, "Mathematics in Transition," The Mathematics Teacher, LIV (January, 1961), 27.

4. The use of sets of elements.
5. The study of both equations and inequalities, that is, statements of equality and statements of inequality.<sup>1</sup>

Modern geometry is built on the sound nature of deductive reasoning and experience in mathematical creativity. Exercises are provided that give the students a chance to discover something for themselves. A greatly curtailed list of required theorems is given and algebraic methods are introduced. The most important new topic in modern geometry is the development of spatial concepts in addition to the concepts of plane geometry. Some of the trends in geometry are as follows:

1. The use of geometric and logical patterns to stimulate pupil discovery and thinking.
2. Careful definitions and the use of precise terminology.
3. Proofs of statements using either coordinate geometry or synthetic methods.
4. An emphasis upon the sets of elements under consideration and the relations among these elements.
5. The integration of some solid geometry with plane geometry.<sup>2</sup>

In advanced algebra, permutations, combinations,

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<sup>1</sup>Bruce E. Meserve, "New Trends in Algebra and Geometry," The Mathematics Teacher, LV (October, 1962), 453.

<sup>2</sup>Ibid., pp. 457.



probability, and mathematical induction are included. Also included are elementary analysis which has as its central concept the idea of a function and an informal intuitive introduction to some concepts of calculus.

In seventh and eighth grade modern mathematics, in addition to the mastery of the four fundamental operations, other number systems with different bases, particularly the binary system are studied. Many of the problems deal with material relating to chemistry and physics. Measurements are taught in relation to industry, geography, and science. Possible error in measurement, relative error, and significant digits are taught along with measurement. Usually a chapter on statistics is included. This includes topics on frequency tables, distributions, histograms, cumulative frequency tables, and various other topics in statistics.

#### WHY REVISION OF THE CURRICULUM IS NECESSARY

The fundamental reason for curricular revision is that the nation's need for mathematics has changed greatly during this century. In 1850 almost no one was engaged in research. Then the members of the general public needed to know how to keep simple accounts and how to solve simple problems in measurement. Bookkeeping required a knowledge of the four operations of arithmetic: addition,

subtraction, multiplication, and division. The problems of measurement encountered in 1850 included the determination of the number of acres of land in a field, of the number of cords in a stack of wood, and of the number of bushels of grain in a bin. The public school courses in arithmetic included a treatment of all of these topics.

Since then many changes have taken place. Space missiles were only symbols of the recent explosions of scientific knowledge in the twentieth century. One of the most important factors contributing to this explosion is the revolutionary advance in both the development and the use of mathematics. The biologist is applying mathematical theory to the study of inheritance; industry is using mathematics in scheduling production and distribution; the social scientist is using ideas from modern statistics; the psychologist is using mathematics of game theory. In fact, the logic of mathematical models shows promise as the basis for developing teaching machines for all areas of knowledge. The new uses of mathematics require less manipulation of formulas and equations but greater understanding of the structure of mathematics and mathematical systems. There is less emphasis on human computation that can be done by machines and more emphasis on the construction of mathematical models and symbolic representation of ideas and relationships. Because of these new



uses mathematics is being firmly woven into the fabric of the national culture. The role of mathematics is not only to grind out answers in engineering problems, but to produce mathematical models that forecast the outcome of social trends and even the behavioral changes of the group. Such important new uses and interpretations of mathematics require that students have a program with a greater depth than the classical program designed for nineteenth-century education. The demands of society require a thorough revision of our present secondary school mathematics curriculum.

These changes that have taken place in mathematics are so extensive, so far reaching in their implications and so profound that they can be described only as a revolution.

One of the first causes for the revolution in mathematics is the tremendous advance made by mathematical research. Because of the nature of mathematics and the failure of research mathematicians to communicate adequately with laymen or even teachers of mathematics the public is unaware of these changes. Mathematics like physics, chemistry, or biology has been transformed by new concepts. New fields have been added to mathematics also: mathematical logic, mathematical statistics, topology, theory of games, information theory, and others. Also the



applications of mathematics has been extended into many new fields. Perhaps the most notable is the field of social science. Psychology, economics, and even sociology are now using mathematical concepts and techniques in much the same way that physicists and engineers used mathematics at the turn of the century.<sup>1</sup>

A second cause for the revolution in mathematics is automation. The automation revolution consisted of the introduction of machines that controlled machines, and of the consequences of the use of such machines. Automation has made possible the construction and operation of machines of enormous size, complexity, and cost; and it has thereby created the necessity for the design and development of such machines. Until fairly recent years, most of the design and development problems were solved by simple experimental procedures.<sup>2</sup>

The introduction of the large-scale, high-speed, automatic digital computing machine is the third cause of the revolution in mathematics. The importance of the electronic digital computing machine arises not from the fact that certain calculations can be carried out more quickly than before, but rather from the fact that

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<sup>1</sup>The Revolution in School Mathematics, pp. 1-3.

<sup>2</sup>Ibid., pp. 3-4.

computations which were formerly completely impossible can now be made quickly and efficiently. Consider the launching of a guided missile. The computing machine remains on the ground, but radar supplies information to it about the flight of the missile. The computing machine makes the necessary calculations and through a radar connection, sets the controls in the missile. The flight of the missile can be influenced only during the period the engine is in operation, a period which is usually not more than two or three minutes. No group of human computers could have possibly received the data, made the necessary calculations and transmitted the results back to the missile in so few seconds. The electronic digital computer handles the problem with ease.<sup>1</sup>

But in spite of these changes that have taken place the traditional mathematics curriculum in the school consists almost entirely of mathematics developed over 300 years ago. No one would complacently teach in our school seventeenth century physics, chemistry, or biology. Everyone is aware that these subjects have been transformed by scientific research. The basic concepts of science and mathematics have changed and new fields have been added, but the curriculum in science has been revised to meet these

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<sup>1</sup>Ibid., pp. 4-5.



changes while the traditional mathematics curriculum has remained relatively the same.

Also many topics that are now included in the traditional mathematics curriculum are obsolete. The teaching of trigonometry and logarithms provides two examples. Trigonometry became a part of the college curriculum in mathematics about 300 years ago when the American colonies were located on the Atlantic seaboard. In the large majority of cases a college graduate became a sea captain, a surveyor, or a minister. A sea captain needed trigonometry for navigation, a surveyor needed it to lay out the farms and cities of the new continent, and the minister needed trigonometry for astronomy. Trigonometry was the all-important applied mathematics of this earlier period and the solution of triangles was its important aspect.

Today, it is found that the important part of trigonometry is the study of the properties of the trigonometric functions rather than the solution of triangles. Radio beams and radar aids have made navigation easy and the new country has been staked out, and only a few, even among the engineers study surveying. The trigonometric function, however, has many important applications, for example, in electrical engineering. Trigonometry is still an important subject in applied



mathematics if the emphasis is placed on analytic trigonometry rather than on the solutions of triangles.

Logarithms were introduced about 300 years ago and they have been widely taught as an important tool for calculation. But logarithms are no longer important for calculations; small calculations are performed on desk calculators and large calculations are performed on electronic digital computers. This doesn't mean we should stop teaching logarithms, but the emphasis should be shifted from logarithms as a tool for calculation to a study of the properties of the logarithm function.

The study of the flow of heat and the distribution of temperatures in a solid body is a problem of great importance at the present time; it was first studied extensively by the French mathematician Jean Fourier early in the nineteenth century. His discoveries had few practical applications at the time, but they have many applications of the highest importance today. Many problems related to the flow of heat occur in the design of every steam power plant, of every air conditioning system, and of every nuclear power plant. The study of the flow of heat, begun by Fourier, and of the mathematical problems which have arisen from this original problem, have had a profound influence on the development of modern mathematics. Some of the changes that are being made in high school

mathematics were designed to provide a better foundation for the study of some of the old problems in mathematics and their modern development. The study of the flow of heat was an advanced problem which could not be studied in high school. Nevertheless, it is important to develop the points of view and to lay the foundation that would permit the student to understand the old problems and the new methods which have been developed to solve these old problems.<sup>1</sup>

Another reason for the change in our mathematics curriculum is that we no longer have just one number system. We have many number systems. The pluralization of the concept of the number system developed in two ways. First, there was a steady expansion of the original number system of every day use. At first the only numbers known were the natural numbers used for counting. The requirements of measurement led to the introduction of rational numbers. Geometric theory led to the introduction of irrational numbers. Algebraic theory led to the introduction of negative numbers and complex numbers. If we recognize as a number system any set of numbers that is closed under addition and multiplication subject to the usual associative, commutative and distributive laws, then

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<sup>1</sup>Ibid., pp. 9-10.



we see that the expansion of the number system has given us five number systems, one within the other. We have the system of natural numbers within the system of integers within the system of rational numbers within the system of real numbers. Second, more number systems were introduced in the course of the development of arithmetic and algebra. In the first place there was modification and elaboration of the concept of the number system by the introduction of the concepts of group, ring, field, and vector space.<sup>1</sup>

The traditional mathematics consisted of learning rules with little understanding of the subject. One university professor made this comment concerning a class of able freshmen.

I had great difficulty, not in teaching them the subject itself, but in getting them to see what it was all about. Their concept of mathematics seemed to be that mathematics consists of a collection of tricks, from which the student must select, without any rational basis for doing so, the right one to<sup>2</sup> produce the answer given in the back of the book.

In a similar vein, another teacher once remarked: "If a student sees a formula in the textbook on the same page as an exercise, he tries to use it, even though it may

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<sup>1</sup>Irving Adler, "The Changes Taking Place in Mathematics," The Mathematics Teacher, LV (October, 1962), 441-442.

<sup>2</sup>Modernizing the Mathematics Curriculum, p. 4.



have nothing to do with the problem."<sup>1</sup>

Since in many of our secondary schools the curriculum consists of the mathematics developed from the "trick" point of view it is not surprising that many students finish the high school course imbued with this same point of view. Instead of trying to find a trick to solve the problem, students should try to discover the nature of the problem with which they are dealing. Teaching mathematics in terms of structure and patterns rather than in terms of rules and tricks, will be greatly facilitated by a curriculum organized from the modern point of view.

As a result of the revolution in mathematics, there is an unprecedented demand for mathematicians and mathematics teachers; it is impossible to foresee a time when there will be an adequate supply. This demand for mathematicians is part of a larger demand for highly trained personnel in all fields. The demand represents a long-term development in our civilization - a civilization which is increasingly dependent on scientific and technological advances. The long-term increase in the demand for highly trained personnel was obscured first by the depression of the 1930's and second by the dislocations caused by World War II. The realization of the true situation burst upon the nation with

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<sup>1</sup>Ibid., p. 4.

startling suddenness in the 1950's, long after efforts should have been initiated to deal with it.

The Rockefeller Report of Education, entitled The Pursuit of Excellence, contained an account of the automation revolution, the accompanying long-term increase in the demand for highly educated personnel and the crisis that confronts the nation. The Rockefeller Report on Education answers the question of how well our educational system is meeting these new demands as follows:

The fateful question is not whether we have done well, or whether we are doing better than we have done in the past, but whether we are meeting the stern demands and unparalleled opportunities of the time. And the answer is that we are not.<sup>1</sup>

The implications of this crisis for our schools is clear. We have to put forth whatever effort is required to insure that the education provided by our schools, - and in particular, the mathematics education provided by our schools - is adequate for the needs of our times.

In summary Kenneth E. Brown has listed the following reasons for revision of the mathematics curriculum:

1. The subject matter of mathematics is constantly growing, not only in the area of advanced mathematics, but also in the area of elementary mathematics.

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<sup>1</sup>The Revolution in School Mathematics, p. 11.



2. Mathematics today is being called on to meet a wide variety of needs of which we had not dreamed of a few years ago.
3. The emphasis in mathematics is changing significantly; it is moving away from human computation to an understanding and construction of symbolic representations of factors that relate to scientific or social situations.
4. New mathematical ideas, language, and symbolism are being introduced to give better understanding of the subject.
5. There is a growing realization of the need for better articulation between secondary mathematics and college mathematics.
6. There is a new awareness that some of the mathematics now being taught in high schools is obsolete and should be replaced by more significant subject matter.
7. A number of educational experiments have demonstrated the feasibility and advantages of teaching new topics in high school mathematics courses.
8. Several national groups of educators have made detailed studies of possible curriculum changes with specific recommendations.<sup>1</sup>

#### THE FORM CURRICULUM REVISION SHOULD TAKE

The recent interest in the mathematics curriculum has brought many professional mathematicians into contact with the secondary school subject matter. The Commission on Mathematics was appointed in 1955 because of the concern

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<sup>1</sup>Kenneth E. Brown, "Improved Programs in Mathematics Require Inservice Education for Teachers," The Mathematics Teacher, LIV (February, 1961), 86.



of the College Entrance Examination Board that their tests were not reflecting fully and appropriately the emerging programs of mathematics instruction in forward-looking college preparatory schools and moreover that the standard curriculum taught in most secondary schools was sadly out of date. Many new programs have now been suggested and new materials have been produced. One major problem which remains to be answered is how this activity in the field of mathematics curriculum development should be translated into an effective mathematics program in the secondary schools.

Many of the groups involved in mathematics curriculum decisions have aided the cause of implementing these programs in the schools through their publicity efforts. There was a continuing need to provide information to both the mathematics teacher and to the administrator in the schools. The Commission on Mathematics of the College Entrance Examination Board led the way in this area by publishing in 1959 the reports, Program for College Preparatory Mathematics and Appendices. Prior to the publication of these reports a series of pamphlets were made available by the Commission on Mathematics to an extensive mailing list of mathematics teachers. A major contribution in mathematics and mathematics curriculum was provided by the National Council to Teachers of Mathematics

with the publication and wide distribution of the pamphlet, The Revolution in School Mathematics. This pamphlet was a report of a series of eight regional conferences which were held in 1960 to acquaint administrators and mathematics supervisors with the developments in mathematics education, so that they could provide the leadership in implementing changes. More and more school systems each year are making decisions to introduce some of the new curricular materials into their secondary school mathematics classrooms, but the introduction of the new materials is certainly no guarantee of an improved mathematics program.

One of the most important points to be made with respect to the actual details of revision is that any proposals should be based on a careful analysis of the curriculum. It should not consist of more or less drastic changes hastily improvised because of the sudden clamor for improvements in science and mathematics teaching that followed the launching of the Russian Sputniks. Such ill-considered proposals as requiring all high school students to take more mathematics, without regard to the suitability of the course content to the needs of the student; introducing courses in calculus without regard to the adequate preparation for this work of either pupils or teachers; placing additional emphasis on manipulative drill without corresponding emphasis upon understanding;



increasing the time for the development of computational skill in trigonometry or advanced algebra - these can all do more harm than good. They accomplish little in the short run, and seriously handicap the progress of necessary changes in the long run.

There are a number of areas in which the present traditional curriculum needs revision. These areas are as follows:

1. Too much attention is given to routine manipulation in artificial situations instead of to the fundamental concepts.
2. Deductive reasoning is taught chiefly in connection with plane and solid geometry and its application to other parts of mathematics is largely ignored.
3. Too often the usual geometry course consists of rote memorization of sequences of theorems and fails to explain the deductive process clearly.
4. Many topics which are now included were important at one time for applied science, but have become obsolete.
5. Many newer topics of importance in mathematics and its applications have been ignored.
6. Mathematics is too often presented as a series of isolated tricks so that students get no view of the subject as a whole.<sup>1</sup>

Modern mathematics has been developed to meet the needs of our changing society. Modern mathematics consists of two viewpoints: new subject matter and a new way of

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<sup>1</sup>Objectives of the Commission on Mathematics of the College Entrance Examination Board, pp. 6-7.



teaching all subject matter. This modern mathematics has shed new light on many standard high school subjects; it has reduced the importance of some of them and increased the importance of others; and it has developed new subjects whose elements are entirely suitable for teaching in high schools.

In mathematics, knowledge of any value is never possession of information, but "know-how". To know mathematics means to be able to do mathematics; to use mathematical language with some fluency, to do problems, to criticize arguments, to find proofs and, what may be the most important activity, to recognize a mathematical concept in, or to extract it from a given concrete situation.

Therefore to introduce new concepts without a sufficient background of concrete facts, to introduce unifying concepts where there is no experience to unify, or harp on the introduced concepts without concrete applications which would challenge the students, is worse than useless; premature formalization may lead to sterility; premature introduction of abstractions meets resistance especially from critical minds who, before accepting an abstraction, wish to know why it is relevant and how it could be used.

Mathematical thinking is not just deductive

reasoning; it does not consist merely in formal proofs. The mental processes which suggest what to prove and how to prove it are as much a part of mathematical thinking as the proof that eventually results from them. Extracting the appropriate concept from a concrete situation, generalizing from observed cases, inductive arguments, arguments by analogy, and intuitive grounds for an emerging conjecture are mathematical modes of thinking. Indeed, without some experience with such informal thought processes the student cannot understand the true role of formal rigorous proof.

Elementary algebra, plane and solid geometry, trigonometry, analytic geometry and the calculus are still fundamental, as they were fifty or a hundred years ago; future users of mathematics must learn all these subjects whether they are preparing to become mathematicians, physical scientists, social scientist, or engineers, and all these subjects can offer cultural values to the general students.

What is bad in the present secondary curriculum is not so much the subject matter presented as the isolation of mathematics from other domains of knowledge and inquiry, especially the physical sciences, and the isolation of the various subjects offered from each other; even the techniques and theorems within the same subject appear as isolated, disconnected tricks to students, who are left in



the dark about origin and the purpose of the manipulations and facts that he is supposed to learn by rote.

In planning a curriculum using modern mathematics and providing instruction for all students with separate interests and abilities we must consider these points:

1. It is not known exactly what career any student will follow.
2. It is not known exactly how the mathematical needs of various occupations will develop in the years ahead.
3. Although much mathematical instruction aims at future usefulness, mathematics for its own sake is a valuable part of the general education of any future citizen.<sup>1</sup>

The mathematics curriculum of the high school should provide for the needs of all students and it should contribute to the cultural background of the general student and offer professional preparation to the future users of mathematics, that is, engineers and scientists, taking into account both the physical sciences which are the basis of our technological civilization and the social sciences which may need progressively more mathematics in the future. While providing for the other students, the curriculum can also offer the most essential materials to the future mathematicians. Yet to offer such subjects to all students as could interest only the small minority of prospective

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<sup>1</sup>Ibid., p. 3.



mathematicians is wasteful and amounts to ignoring the needs of the scientific community and of society as a whole.

In changing the mathematics curriculum two types of students have to be considered: those needing mathematics for general education and those needing mathematics for professional education. For general education the objective is to teach the students the basic mathematical ideas and concepts which every citizen needs to know and to explain the essential character of mathematics - how it is used to arrive at conclusions about our actual world, and how it can contribute through its aesthetic values to personal, intellectual satisfactions of individuals. More specifically, the goals of this type of mathematical education are:

1. Thorough competence in the processes of arithmetic and the use of formulas in elementary algebra and a basic knowledge of simple statistics and of graphical methods.
2. An understanding of the general properties of geometrical figures and the relationships among them.
3. The understanding of the deductive method as a method of thought.
4. The understanding of the ideas of statistical inference as a method of drawing conclusions based on incomplete information.
5. An understanding of mathematics as a continuing

creative endeavor with aesthetic values similar to those found in art and music.<sup>1</sup>

The goals of professional education are dependent on the plans of the individual students. However, the basic principle in determining the content of the curriculum should be that those topics in mathematics should be taught which the students will encounter later on. These topics should not only be determined by applications of mathematics in physical science, but the developing applications in social science and biology can no longer be ignored. This program must concentrate on the most important, long-range ideas, and the utility of a particular subject must be judged on the basis of the best current practice in the field, not merely upon its traditional reputation for usefulness.

A central challenge and one that a school should think about when deciding what form curricular revision should take, is the basic challenge to develop the best possible body of mathematical content suitable for presentation at each educational level from the elementary school through the graduate level of the university. In recent years, related sub-challenges have been emerging. These are as follows:

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<sup>1</sup>Ibid., p. 4.



### Moderns Versus Traditionalists

There exists today a modern school of thought which recommends that the content of school mathematics should include a maximum amount of the newer mathematics discovered in recent centuries. This recommendation is partially based on the hope of thereby providing for students mathematical material that may be less obsolete and more illuminating and interesting.

Another school of thought - the traditional school - has recommended that the content of school mathematics should preserve the maximum amount of the fundamental mathematics discovered in the earlier history of mathematics. This recommendation is partially based on the hope of thereby providing for students mathematical material that may be less abstract and more fundamental and useful.

Mathematics teachers have varied degrees of reaction to the claim of the "moderns" that students may easily learn certain elementary concepts of modern mathematics. They vary also in their reaction to the countercharge of the "traditionalists" that children may easily learn concepts of even the most useless types of material and that the basic challenge is to select the most useful mathematics that may be taught in a very limited period of education. Thus the challenge to mathematics educators is to determine - with the aid of careful research - the



necessary and sufficient amounts of content of "modern" and "traditional" mathematics suitable for students of current school mathematics.<sup>1</sup>

### Mathematics Versus General Culture

Partly as a result of tensions created by the current "cold war" between the United States and Russia, the importance of mathematics in school curricula has been increasingly realized. On the one hand, some have asserted that, to meet the Russian challenge, the total school curriculum should be revised to include more mathematics for all students. On the other hand others have asserted that our times demand a more vigorous total education which would properly treat other enlightening subjects in our general culture. The challenge, then is to place mathematical and non-mathematical subjects in the proper perspective, and thus, to determine the extent to which such subjects may even enhance each other on every level of the educational ladder.<sup>2</sup>

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<sup>1</sup>Herman Rosenberg, "Great Challenges of Mathematics Education," The Mathematics Teacher, LV (May, 1962), pp. 360-361.

<sup>2</sup>Ibid., p. 361.

### Pure Mathematics Versus Applied Mathematics

As current efforts are made to increase the content of "pure" school mathematics within allotted time limits, it becomes apparent that some aspects of school mathematics must give. There are those who believe that concepts of applied mathematics should be among the first victims on the sacrifice list. The conviction here is that applications of mathematics may be learned automatically or easily in later years. There are also those who believe that concepts of applied mathematics should be relinquished only with the greatest care. The conviction here is that such applications may not be learned automatically and may be vital and convenient vehicles not only for motivating instruction but also for providing mathematical insight and knowledge of our general culture.<sup>1</sup>

### Integration Versus Segregation

Several schools of thought are concerned with the proper type of organization of the content of school mathematics. Members of the integration school recommend that the content of school mathematics should be organized in a manner as integrated as possible. They feel that when several branches of mathematics are merged in one mathematical course, there may be significant gains for students

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<sup>1</sup>Ibid., p. 361.

in mathematical power, illumination, and appreciation. Integrationists point out that because of the same abstract structure of certain branches of mathematics such as algebra and geometry a student temporarily blocked in finding a solution via geometry may find the solution via algebra. They argue that the trend in development of modern mathematics is toward integrated mathematics and that school mathematics should reflect this trend.

Members of what may be called the segregation school of thought recommend that the content of school mathematics should be organized in a manner as segregated as possible. They feel that an understanding of the structure of each branch of mathematics is best obtained by studying that branch in orderly isolation from other branches. They have the impression that integrated school mathematics is likely to be a bewildering hodgepodge for students.

Intermediate positions may be occupied between the integration and segregation schools of thought. Some mathematics teachers feel that even when the teacher of segregated or pure algebra confronts the student with the elementary problem of adding  $3x$  and  $5x$ , the necessity for student use of at least the skills of arithmetic may be a natural triumph for integration. Some point out that, in at least one sense all effective learning may be integrated learning as a new concept effectively added to previously



learned concepts. Others insist that the fundamental concern is not the integration of one concept with a large set of concepts but rather the integration of two large sets of concepts. And they emphasize the belief that learning may be facilitated if the purposeful integration of such sets of concepts takes place after each set has been learned separately. This is the challenge to mathematics educators to determine the desirable amount of both the segregation and integration of concepts of school mathematics.<sup>1</sup>

#### Revolutionaries Versus Conservatives

Some educators have proposed what has been described as revolutionary reforms in the content of school mathematics. The justification given for the rapidity of such revisions has often been the need for meeting the dangers involved in the rapid expansion of various foreign powers. Other educators have contemplated in horror the possibility of hasty programs that may destroy sound aspects of school mathematics that currently need conserving.

Between the extreme poles of dynamic revolution and static conservation is a group of educators who favor changes of a gradual nature. Some feel that rapid, revolutionary change in school mathematics programs may

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<sup>1</sup>Ibid., pp. 361-362.

bewilder, confuse, and discourage unprepared teachers ordered to conform rapidly and that revolutionary change may permit for teachers a gradual, pleasant, stimulating growth. Advocates of more rapid change argue that in dangerous times, such as the present, we may no longer afford the luxury of leisurely change in school mathematics. Thus, the challenge to mathematics educators is to determine the correct speed for reforming the content of school mathematics and the appropriate methodology for ascertaining the speed.<sup>1</sup>

#### Diversity Versus Unity

On the one hand, members of a diversity school of thought prefer a maximum amount of experimentation with varied programs of content for school mathematics. They feel that diversity in content is necessary for differing students, teachers and schools and is desirable for those who seek mathematical insight via alternative structures of the same content. They also hope that experimentation may lead ultimately to the most desirable possibilities for selecting and organizing school mathematics.

On the other hand members of a unity school of thought prefer a maximum amount of agreement on the nature of the content of school mathematics especially using the

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<sup>1</sup>Ibid., pp. 362-363.



same symbols for the same content. The challenge to mathematics educators is to develop a program of school mathematics content that reflects the efficiency and advantages of unity within the beneficial experimental framework of diversity.<sup>1</sup>

### Challenges of Method

In addition to these challenges of content, many other challenges await mathematical educators. A basic challenge is the challenge to develop the best possible methodology for teaching mathematics at each educational level from the elementary school through the university. In recent years at least five related subchallenges of this general methodology challenge have been emerging.

Logical versus psychological. At the present time, many mathematics educators have been very much concerned with a lack of rigor in much of school mathematics. Some, for example, may be well aware of the many logical holes discovered in secondary school geometry and they may wonder about the possibility of using in secondary schools the more rigorous Hilbert approach to Euclidean geometry. Such views are frequently based on the feeling that mathematics must be presented logically if teachers are to achieve with

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<sup>1</sup>Ibid., p. 363.



their students all the potential disciplining thinking values of mathematics.

In general, mathematics teachers realize that as mathematicians, they wish the mathematics they teach to be as logical as possible. And as teachers, they wish to teach that mathematics in accordance with the soundest findings of educational psychology. The challenge for mathematics educators, then is to provide curricular experience in mathematics that are soundly based on the best traditions of both logic and psychology.<sup>1</sup>

Needs theory versus subject matter theory. There are varying emphasis given to the relative importance of the mathematics taught to students and the needs of such students. These needs, for example may include adequate amounts of challenge garnished by superior teachers and materials of instruction. A basic challenge here is to develop methodology for improving the sensitivity of teachers and administrators to the importance of both mathematics and the mathematically oriented needs of their charges.<sup>2</sup>

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<sup>1</sup>Ibid., p. 364.

<sup>2</sup>Ibid., p. 364.

Differentiated versus non-differentiated. Recent decades have witnessed changing viewpoints with respect to the desirability of differentiating instruction to provide for tremendous individual differences in ability and interest among mathematics students. Under the impact of the Sputnik race, respect for homogeneous grouping of mathematics students has been increasing. Nevertheless even among mathematics educators strongly convinced of the desirability of homogeneous grouping, there exists some division on questions such as these:

1. At a given educational level, should groups of slow and rapid learners be taught the same basic mathematics content or should differentiation be provided in content as well as in teaching method.
2. Should groups of rapid learners experience acceleration in learning time or enrichment of mathematical content.
3. Should different grading systems be used to distinguish between mathematical achievement in slow and rapid classes.
4. What is the optimum size for differentiated mathematics classes.

In general, the challenge to mathematics educators is to determine and increase the effectiveness of mathematics classes in which there has been differentiation with respect to mathematical content and/or teaching methods.<sup>1</sup>

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<sup>1</sup>Ibid., p. 365.

Field theory versus association theory. Different psychologies of learning affect the choice of teaching methods. Some educators favor the association theory and thus they emphasize the importance of student learning of specific items of content with proper amounts of drill and programming. Others favor the field theory and thus, they emphasize the importance of structure of mathematics or mathematical systems. The challenge here is to develop a workable theory of maximum learning of mathematics, utilizing the best aspects of such theories as the association theory for learning the small parts of mathematics and the field theory for learning the large whole of mathematics.<sup>1</sup>

Inductive method versus deductive method. Some mathematics educators have long employed in their textbooks and classrooms a deductive approach to the teaching of mathematics. Here, a mathematical generalization is presented first and is then followed by applications to specific situations. Others have advocated the use of an inductive approach, where specific situations are presented first and are then followed by student discovery of a mathematical generalization. The challenge here is to

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<sup>1</sup>Ibid., p. 365.



determine the conditions under which maximum learning is possible via both deductive and inductive approaches to the teaching of mathematics.<sup>1</sup>

General practitioners versus specialists. Varied suggestions are available when one seeks a desirable program for the education of mathematics teachers. In the area of the pre-service training of teachers of secondary school mathematics, there exist differences in viewpoint on the proper relative amounts of specialization and general education. Here, too, there are different views with respect to the desirable distribution of specialization courses and the relative importance of content courses and courses in teaching methodology. The challenge, then is to evaluate the best types of both general and specialized education of mathematics teachers - an education characterized by balance in both depth and breadth and in content and methodology.<sup>2</sup>

Evaluation of mathematics instruction: skills versus meanings. While the importance of evaluating instruction in mathematics has been generally recognized, there have been different identifications of the specific aspects of

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<sup>1</sup>Ibid., p. 365.

<sup>2</sup>Ibid., pp. 365-366.

instruction needing evaluation. Some have insisted that the basic task in mathematics education is the development of student skills in mathematics and that consequently, the basic job of mathematics evaluation is the testing of such skills. Others have maintained that the truly important task in the teaching of mathematics students of the meanings of mathematical concepts and that, consequently, the basic job of mathematics evaluation is the testing of such understandings.

Thus, the determination of what should be evaluated depends upon the choice of the goals and potential values of mathematics teaching. When seen broadly, the fundamental challenge to mathematics educators is the challenge to determine precisely those objectives of mathematics education that may assist in securing for students and society-at-large the good life and then to prepare a total program of evaluation of all aspects of the program of mathematics education designed for those objectives.<sup>1</sup>

Leadership: school versus community. There have been pronounced differences in viewpoints with respect to the leadership role to be played by society, on the one hand, and school personnel, on the other hand. Some have

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<sup>1</sup>Ibid., p. 366.

advocated that the schools should not only utilize the local community for resources in the teaching of mathematics but also encourage members of the community to assume a leading role in matters of school reforms such as improvement of inadequate salary structures for mathematics teachers for professional growth. The challenge, then, is to determine and to secure the finest types of educational leadership affecting mathematics education and to utilize the most able personnel from both the school and society.<sup>1</sup>

Even though more and more schools are making decisions to introduce some of the new curricular materials into their schools any proposals should be based on a careful analysis of the curriculum. All students' needs and abilities should be considered. In summary the Commission of Mathematics states three principles which must be regarded as fundamental in any solution of curricular revision.

1. The proposals must be based on the existing curriculum and must consist of modification, modernization and improvement of the present pattern, rather than its discontinuance and replacement by entirely new content.
2. The point of view of modern mathematics must be used as a guide in determining the modifications to be made.

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<sup>1</sup>Ibid., pp. 366-367.



3. Changes to be proposed must be sufficiently far reaching so that the modified curriculum is truly oriented to the present and future needs but not so radical as to be beyond the competence of the available teaching staff.<sup>1</sup>

## IMPLEMENTING A MODERN MATHEMATICS PROGRAM IN THE SECONDARY SCHOOLS

Since each school is unique in some respects, it must ultimately develop its own program which will be unique in spite of a great many similarities to programs in other schools. The problem of introducing a new mathematics program into secondary schools is very complex. There is no one formula that works for all schools. This is because schools vary in size from the very small with fewer than 100 students to a very large one with several thousand students. The percentage of college-capable students also varies greatly from school to school. Another reason is that the capabilities and training of the mathematics teachers vary greatly. Then community attitudes toward mathematics programs vary. Some communities display complete apathy and unwillingness to disturb the status quo. Other communities show enthusiasm for change, but meet resistance from faculty members untrained in the newer approaches to mathematics.

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<sup>1</sup>Modernizing the Mathematics Curriculum, p. 7.

The following eight steps are considered basic to the implementation process. Each of these will be discussed later describing and evaluating the techniques involved.

1. Recognition by school authorities of the need for a new mathematics program.
2. Adequate preparation of teachers in the mathematics now being taught for the first time in secondary schools.
3. Selection of new programs.
4. Selection of students for the program.
5. Informing parents about the new program.
6. Informing other members of the school system about the new program and its implications for the mathematics program kindergarten - twelve.
7. Continuation of teacher preparation for carrying the new program to higher and lower grades.
8. Provision for adequate time and compensation to carry on the new program year after year.<sup>1</sup>

### Recognizing the Need

The first of the eight steps is really a prerequisite of change, since the need must be recognized by school authorities before any change can be made. School authorities include mathematics teachers and supervisors, superintendents, principals, and their assistants in charge of curriculum development, and the school committees or school boards or any personnel responsible in any way

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<sup>1</sup>The Revolution in School Mathematics, p. 38.



for the school mathematics curriculum.

To recognize the need for a new program, authorities must first realize the existence of such a program. Many teachers have become interested in new mathematics programs as a result of reading reports in various professional magazines and journals. Teachers have learned about the new programs and new texts at mathematics institutes and they often return to their own schools and inspire colleagues to compare the traditional mathematics program with one of the newer ones.

Principals and superintendents in some schools have urged teachers to attend summer institutes or academic-year institutes. Some teachers have said that they were ready to start a new program in mathematics, but they could not get the administration to cooperate. Money to help implement the program was not available. Implementing a new mathematics program is really a cooperative venture for both the mathematics teachers and the administration. But it is clear that teachers recognize the need for change as soon as they learn about the newer mathematics that is being taught successfully in secondary schools.

#### Adequate Preparation of Teachers

The next important consideration in any discussion of curricular revision in mathematics is the availability of teachers able and willing to offer instruction in the



subject matter included in the curriculum. In-service and pre-service education of teachers will be needed to accomplish this. Nearly all the major groups recommending changes in the mathematics curriculum at the secondary school level and developing new materials for the classroom have been concerned with the problem of in-service preparation of teachers.

There are five main categories into which the various in-service efforts can be organized. There are college-level credit courses, formal courses organized in the local school with outside help but without credit, informal courses organized in the local school with no outside help, individual study by teachers of mathematics, and a variety of indirect or short-term methods.

The college-level credit course is probably one of the best ways to improve the competence of the mathematics teachers and prepare the teacher for introducing a new mathematics program. There are several ways in which the teacher can avail himself of the opportunities for in-service education through college credit courses. The academic year institutes, summer institutes, and in-service institutes of the National Science Foundation have offered one of the major opportunities for the mathematics teacher to return to the classroom as a pupil. However, the course must be designed for the high-school mathematics teacher at

the level at which he is at the present time. The Commission on Mathematics of the College Entrance Examination Board was particularly concerned with the lack of appropriate courses for the high school teacher returning to formal college classroom work. Neither the advanced mathematics courses in the university with an emphasis on training research mathematicians nor education courses in methods were appropriate for in-service courses for teachers for the purpose of implementation of a new curriculum. The Commission pointed out that there should be cooperation between the department of education and the department of mathematics in the university to bring about effective subject-matter courses for secondary school teachers of mathematics. Although the problem is still acute, the experiences, both good and bad, that colleges have had with National Science Foundation Institutes for teachers have brought about the development of many new courses more appropriate for high school teachers.

Every university mathematics department should feel obligated to give very careful attention to the materials and methods made available to those who plan to teach mathematics in the secondary school. Heretofore, not enough effort has been expended in the preparation of suitable content courses for prospective teachers. Special attention has always been given to supply the mathematical



content needed for the architect, the engineer, the scientist, the economist, and the major in mathematics. It would seem logical to expect as much or even more consideration to mathematics teachers who are obligated to arouse and hold the interest and training of the youth of the land as they teach mathematics.

Undergraduate programs of colleges and universities should be modified at once to provide a sound background of study of contemporary mathematical material and to produce teachers adequately equipped to deal with the new curricular patterns. It is clear that what is needed are new courses designed for and geared to the needs of mathematics teachers. Departments of education and departments of mathematics should be encouraged to cooperate in setting up and administering such programs. Some university mathematics departments seem to assume that all prospective mathematics teachers will be able to knot together the ideas gathered from their mathematics courses in such a manner that they will be adequately prepared to be teachers of high school mathematics. There are altogether too many recently graduated teachers who go into the high schools and teach the same old algebra and geometry in the same old way that teachers have been teaching for decades. It demonstrates so nicely the tendency possessed by so many of us to teach only what and how we have been taught. So, we



find ourselves drilling and drilling for skills until we find no time left to give proper attention to the molding together of these concepts, principals, and relationships that are so basic in the building of a sound mathematical structure.

Particular emphasis should be given in college to the courses offered in the freshman and sophomore years because, of all the courses in college, these should be the most closely related to the high school courses. The spirit in which these courses are presented and the content of these courses can greatly influence not only the spirit and content of school mathematics but the method in instruction. If college courses are taught mechanistically without proper consideration of mathematical structure and present-day knowledge of the learning processes, then secondary school mathematics courses will probably be taught mechanistically without thought of method or content. So colleges should give careful consideration to what mathematics is taught and how mathematics is taught to the prospective high school teacher.

The second general category of in-service programs for teachers is the course organized in the local school with outside consultant help. As new curriculum programs are introduced into the local schools, this is no doubt an increasingly used method in in-service education. The

outside consultant is a college professor of mathematics, a mathematics educator, or a professional mathematician. Since the course is offered to a particular school staff, the course can be directed at a particular grade level and the introduction of specific curricular materials.

Informal courses for teachers could be organized within a school system with no outside aid. In the large city school system this is possible, since there are often specialists in mathematics education available for initiating and carrying forward such activities. In the smaller school districts, there are sometimes well-trained teachers who can take over such responsibilities. Many of the mathematics teachers are prepared for this task after they have participated in summer institutes or academic year institutes. Much of this type of activity is accomplished within the framework of the established departments of mathematics in the school.

All of these credit, formal, and informal group activities in in-service education for the mathematics teachers of the secondary schools should utilize some of the techniques and materials that are available. The experience of the same programs with demonstration teaching might indicate that this form of activity should be a part of an in-service course. The use of films of classroom teaching might form an integral part of these courses.



Individual study by teachers in the secondary school not only should be encouraged, but should be expected. There are many opportunities for study, even though formal or informal courses might not be available. For years there has been a rather complete void in the literature appropriate for this independent study. Now publications are becoming available.

The School Mathematics Study Group has been actively interested in the in-service preparation of mathematics teachers and has prepared materials which were designed specifically for this purpose. In the SMSG Experimental Centers, approximately a half a dozen classroom teachers were brought together with a subject matter expert who provided the necessary mathematics training for the teachers to teach one of the SMSG courses. The SMSG reports that the use of a subject-matter specialist, usually a college or university mathematician, in an in-service training program with the teachers during or before the first years use of an SMSG text provides the additional mathematical background for teachers to successfully teach the course. The SMSG reported that this help was only needed once, and the teacher can then handle the course successfully without further help from a subject matter specialist.

The School Mathematics Study Group has produced

materials specifically designed for use with teachers in in-service courses or in individual study situations. With the exception of the work done in the Experimental Centers, the SMSG has not been itself actively engaged in the training of mathematics teachers. The National Science Foundation, which provides the financial backing for the School Mathematics Study Group, has been very active in providing in-service opportunities for teachers of mathematics and science. The Foundation provided extensive support for the program of academic year institutes, summer institutes, and in-service institutes staffed by mathematicians and scientist of recognized competence in their specialties. These institutes have been supported by the National Science Foundation since the mid 1950's.

The University of Illinois Committee on School Mathematics probably was the most actively concerned with the in-service preparation of the teachers who are teaching the new materials being produced. The in-service teacher-training program of the UICSM took several forms. The Teacher's Commentary, which was an integral part of each of the Teacher's Editions of the text materials produced, was aimed at in-service education. The commentaries considered the mathematics which was behind the test materials and also the rationale for presenting the materials in the manner in which they appear in the text. Before the initiation of



summer institutes the UICSM staff worked with the teachers in the pilot schools primarily through the use of demonstration teaching. Demonstrations with actual classes were considered so important that a series of films were developed for the use of groups which did not have opportunities to observe live classes. These demonstration classes were found to be most successful when they involved teaching the actual materials which the teachers are studying and planning to teach their students.

The Boston College Mathematical Series consisted of teacher-training materials as well as textual materials for the classroom. The work at Boston College has involved the development of a course which an individual teacher can undertake without outside assistance. The course is known as the Co-op Unit of Study Program. This self-study course is designed to acquaint teachers with both the historical background of much of the mathematics and many of the newer ideas in mathematics being introduced into the school curriculum.

There are a number of indirect and short-term forms which in-service education can take. The attendance of teachers at professional meetings often serves an in-service function. Even though this may not bring them into depth in the subject area, the stimulation is often provided which carried the teacher into extended programs of study. The

participation of teachers on curriculum study committees is a form of in-service education. This could take place at the local school level or perhaps state level. The intervisitation of classes by mathematics teachers is another important form of in-service training. The opportunity to see new ideas at work in another classroom is often worth a great deal in convincing a teacher of the value of new curriculum materials.

There are two important elements which should be considered in any discussion of the various forms that in-service education should take. Financial support and released time for the teacher are necessary.

In the credit courses, the National Science Foundation has paved the way by providing free tuition. Where this isn't available the school system has to carry the heavier share of the burden by providing tuition costs for teachers. When outside consultants are brought into the school, the school system would have to be prepared to pay full costs of the consultant for materials that teachers would use.

Not only financial support is necessary, but time is an essential factor. Schools in the future will have to be prepared to allow teachers to upgrade their competencies during normal working hours. Extra duties not connected with mathematics teaching should be kept to an absolute



minimum. If a school system seriously wants to improve the mathematics program in its secondary schools, both released time and financial support is necessary.

In actual practice it is not desirable to isolate one particular form of in-service program or to outline the exact steps involved in the implementation of a new mathematics program. There is an interaction among the many forms of in-service education and there is much simultaneous action and overlapping in the implementation of a new program. One of the discussion groups at the conference held on in-service education of high school mathematics teachers in Washington listed the following among a list of elements of a good in-service program.

1. Is coordinated within school levels from one grade to the next.
2. Is developmental in that it is continuous and adjustable to the needs of the classroom teacher and the changes in curriculum development and implementation.
3. Recognizes the individual differences among teachers, differences that reflect pre-service training, length and variety of teacher experience, and grasp of subject matter.
4. Makes provision for teachers to play some part in setting up the program of in-service training.
5. Is developed in an emotional climate which inspires confidence in the participants and indicates administrative support.
6. Takes into account the needs and abilities of all the children: the slow learner, the retarded, the underachiever, the average, and the gifted.

7. Is closely integrated with the supervisory and guidance program of the school.
8. Develops a variety of approaches to teacher growth.
9. Is judged for its effectiveness at regular intervals through various techniques of appraisal.
10. Draws upon the resources of the community, the colleges, and universities and the professional staff itself.
11. Is aware of the limitations on teacher time and daily load, and makes reasonable adjustments for teachers participating in the program.
12. Gives recognition and encouragement to active participants in the program in terms of promotional opportunities, financial remuneration, salary increases and professional status.<sup>1</sup>

However, the real problem is still with the individual school district. No one set of guidelines, no single set of steps of implementation will suffice. The modernization and improvement of the course materials will not assure any improved teaching in the field of mathematics. Better mathematics programs in the school are primarily a function of the performance of the teacher in the classroom.

#### Selecting the Program

The third step in implementation, after the teachers have learned some of the newer approaches to mathematics, is

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<sup>1</sup>James Henkelman, "Implementing a New Mathematics Curriculum," The Mathematics Teacher, LVI (April, 1963), p. 217.



the selection of a new program. Some curriculum changes that are recommended in any program are given by Kenneth E. Brown. They are as follows:

1. Includes the elementary concepts and language of sets.
2. Teaches a more refined concept of a function.
3. Strengthens the logical development of geometry.
4. Presents in plane geometry some of the elements of analytic geometry and solid geometry.
5. Modernizes the vocabulary of elementary algebra.
6. Studies inequalities as well as equations.
7. Stresses understanding rather than manipulation.
8. Cultivates an understanding and appreciation of structure of mathematics.<sup>1</sup>

It is important that teachers be somewhat acquainted with the various new mathematics programs and that they take an active part in the selecting and planning such a program. Teachers should have had ample time and warning before they are required to teach such a program. All teachers are urged to put as much as possible of the new mathematics content into their secondary school classes even without changing the textbook. The courses can be improved immediately if teachers will study, learn, and

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<sup>1</sup>Kenneth E. Brown, "Improved Programs in Mathematics Require Inservice Education for Teachers," The Mathematics Teacher, LIV (February, 1961), p. 87.

teach the content of the new programs even though it is not in their textbooks. SMSG (School Mathematics Study Group) and UICSM (University of Illinois Committee of School Mathematics) and other various materials are available as supplementary helps.

One typical modern mathematics course in Kanawha County, West Virginia, is outlined as follows:

- 7th Accelerated Arithmetic
- 8th Elementary Algebra
- 9th Intermediate Algebra
- 10th Combined Plane and Solid Geometry
- 11th Trigonometry and College Algebra
- 12th Mathematical Analysis<sup>1</sup>

The seventh-grade arithmetic course was designed to include material previously taught in the country in the seventh and eight-grade arithmetic courses. The course was planned to give students an understanding of our number system, the application of the fundamental operations to problem-solving in household mathematics, business practice and measurement, and to introduce the students to the study of algebra and geometry. Some of the operations of sets and the vocabulary of modern mathematics is introduced in this grade.

The eighth-grade algebra course was similar to the elementary algebra course usually taught at the ninth-grade level. The vocabulary and concepts of modern mathematics

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<sup>1</sup>B. G. Pauley, "An Evaluation of a Secondary-School Mathematics Program for Able Pupils," The Mathematics Teacher, LIV (May, 1961), p. 324.



were extended. Emphasis was placed on the idea of leading pupils to develop concepts through meaningful mathematical experiences. The concept of proof, both algebraic and geometric, which was introduced in the seventh grade, was extended. The course covered the usual topics through quadratic equations. Some additional topics, such as descriptive statistics and numerical trigonometry of the right triangle were added.

The ninth grade intermediate algebra course was also similar to the intermediate algebra course usually offered in the eleventh or twelfth grade. Again meaning was stressed. Concepts were developed and extended by the student through meaningful experiences. Students were trained to discover why. Algebraic proofs were developed. The idea of the set as a unifying concept was emphasized. Topics taught included logarithms, imaginary and complex numbers, systems of equations, polynominal functions, trigonometry, progressions and series and permutations, combinations and probability.

The integrated course in plane and solid geometry taught in the tenth grade was based on the assumption that the essential concepts in solid geometry could be taught best by relating them to similar concepts from plane geometry. The students learned the relationship existing between two perpendicular planes, for example, as an

extension of the relationships existing between two perpendicular lines.

The course in trigonometry was designed to occupy one semester in the eleventh grade. A strong emphasis was placed on the theoretical aspects of the subject. Topics were covered in such a way as to extend the student's knowledge of mathematics as a logical structure, rather than making the course one in plane surveying.

The college algebra course which occupied the second half of the eleventh grade, was designed to approximate a course by the same title which would be offered to first or second-year college students. Topics taught included theory of equations, inequalities, complex numbers, progressions, infinite series, variations, permutations, combinations, and probability, statistics and limits.

The course in mathematical analysis taught in the twelfth grade was a combination of analytic geometry and differential and integral calculus. The course was not designed to replace a college calculus course but designed to prepare students adequately to begin their college mathematics program at the calculus level.

Students were selected for this program who had demonstrated a high level of academic achievement and a high IQ. Results in this program were divided into two categories; the results from a questionnaire sent to



students and teachers involved in the program and standardized test results.

The results from the questionnaires showed that this program was accepted and favored by almost everyone concerned. A great majority of the students questioned reported that they liked these special classes better than the mathematics classes in which they had been previously enrolled and that their parents like having them in the classes. The students also said that they had learned more in the classes although a number of pupils said that they had been required to work harder.

Teachers unanimously reported that they had found the program to be satisfactory and were almost unanimous in saying that they felt that students had made more progress in these special classes than they would have made in the regular mathematics program. The teachers said also that the student's attitudes had improved and that their parents had reacted favorably to the classes.

Some of the teachers helping with the planning of the program were concerned with the effect that placement in special classes, such as one of the classes in the program, might have on the pupils inter-personal relations. Teachers reported though that the attitudes of pupils placed in the program toward their fellow pupils who were not so placed were not noticeably affected.

Standardized achievement test results showed the seventh-grade arithmetic pupils in the program to be almost three years ahead of national norms. Eight-grade pupils completing first-year algebra were found to be well above the national norms for ninth-grade algebra students. Similarly, ninth-grade pupils taking intermediate algebra were found to be well above the national norms for eleventh-grade pupils. Achievement tests in plane and solid geometry also showed pupils the test results generally indicated that the program was proving to be successful, comparisons were not made of the results obtained in these selected sections with results obtained in the regular mathematics sequence existing.

It might be well to mention here that not all experimental groups have found that there is an advantage to a modern mathematics curriculum. In 1960 the Roseville School System in Minnesota carried out an experiment using SMSG materials to one group and Roseville traditional materials to another group. This experiment took place in the seventh, eight, and ninth grades. The experiments returned results which showed no advantage as far as the test used could measure, for classes taught with SMSG



materials.<sup>1</sup>

There are also many other improved mathematics programs now in progress. There are many similarities among the different programs, but there are also differences - both in development and in emphasis. One program may have involved many more persons in its development than another; one program may have been tried in many cities in the United States and another confined to a local region; one program may have material for grades seven through twelve and another for only some of these grades; one program may emphasize the discovery method and another the historical approach. A brief summary of some of the programs available is as follows:

School Mathematics Study Group. The School Mathematics Study Group (SMSG) represents the largest united effort for improvement in the history of mathematics education. It is national in scope. The development of the SMSG material is unique in that it represents the combined thinking of many people - psychologists, testmakers, mathematicians from colleges and industry, biologists, and high school teachers. Approximately 199 mathematicians

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<sup>1</sup>Emmet D. Williams and Robert V. Shuff, "Comparative Study of SMSG and Traditional Mathematics Text Material," The Mathematics Teacher, LVI (November, 1963), p. 504.

and 100 high school teachers did the writing, and in order to produce material that is both mathematically sound and teachable, each writing team had an equal number from each group.

During the school year 1959-60 sample textbooks and teachers' manuals for grades seven through twelve were tried out in forty-five states by more than 400 teachers and 42,000 pupils. During this tryout the teachers received guidance and consultative assistance from college mathematicians.

Throughout the year detailed evaluations of each chapter of the sample textbooks were submitted by teachers, mathematics advisers, and in some cases by the pupils themselves. All the suggestions and criticisms were studied and analyzed by the revision writing team composed of approximately fifty high school teachers and fifty mathematicians. The revision team made many changes - sharpening the discussion, giving better choice of graded exercises, and rewriting certain troublesome spots. They also rewrote those areas identified by the pupils as especially troublesome or difficult. Despite these revisions, it is significant that no changes were suggested in the basic mathematics or philosophy of the original material.

The SMSG textbooks contains new topics as well as



changes in the organization and presentation of older topics. Attention is focused on important mathematical acts and skills and on basic principles that provide a logical framework for them.<sup>1</sup>

University of Illinois Curriculum Study in Mathematics. The University of Illinois Curriculum Study in Mathematics (UICSM) is a joint effort, by the College of Education, the College of Engineering, and the College of Liberal Arts and Sciences at the University of Illinois. The textbooks emphasize consistency, precision of language, structure of mathematics, and understanding of basic principles through pupil discovery. Discovery of generalizations by the student is a basic technique used throughout the course.

Work on the UICSM material began in 1952, and by the end of 1959-60 school year the material had been used experimentally in twenty-five states by 200 teachers and 10,000 pupils. Participating teachers have received detailed instructions on the use of this experimental material from the Illinois Center.<sup>2</sup>

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<sup>1</sup>The Revolution in School Mathematics, pp. 54-55.

<sup>2</sup>Ibid., pp. 53-54.

University of Maryland Mathematic Project. The University of Maryland Mathematics Project (UMMaP), was designed to develop an improved mathematics program for grades seven and eight. Five mathematicians and approximately forty teachers took part in planning and/or writing the experimental program, with consultative services from specialists in such other areas as psychology and testing.

Although the original experiment was confined primarily to nearby schools the books have now been used in ten states by about 100 teachers with 5,000 pupils.

The courses are designed to serve as a bridge between arithmetic and high school mathematics. Unusual chapter titles such as the following appear in the seventh grade textbook: "Systems of Numeration", "Symbols", "Properties of Natural Numbers", "Factoring and Primes", "The Numbers One and Zero", "Mathematical Systems", "Scientific Notation for Arithmetic Numbers", "Logic and Number Sentences."<sup>1</sup>

Boston College Mathematics Institute. The Boston College Mathematics Institute provided material for grades eight through twelve. Historical development is used to break away from the traditional approach as well as to give the pupil an opportunity to exercise his imagination and

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<sup>1</sup>Ibid., pp. 55-56.



creativity and to encourage him to do some reading. Mathematics is studied through problems that confronted primitive man and questions currently being answered by mathematicians. The emphasis is on the structure of mathematics approached from the historical point of view.<sup>1</sup>

Ball State Teacher College Experimental Program. The Ball State Teachers College Experimental Program is planned for pupils in grades seven through twelve. The program emphasizes the axiomatic structure of mathematics and precision of language. As results of experimentation at the Ball State Laboratory School, Muncie, Indiana, materials for grades eight, nine, and ten have gone through several revisions. The texts for algebra one and geometry are characterized by careful attention to logical development. Both the algebra and the geometry contain carefully constructed chapters on elementary logic. These chapters appear early in the texts and the ideas developed in them are utilized continually in both courses.<sup>2</sup>

Most sources of material did not recommend the inclusion of a course in calculus as a part of the normal high school curriculum. The average student could not be

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<sup>1</sup>Ibid., p. 56.

<sup>2</sup>Ibid., pp. 55-56.

adequately prepared for such a course in three years, anything less than a full year course would ordinarily be time wasted since it would not fit into any typical college program. Moreover, a course in calculus should deal with ideas that are mathematically quite sophisticated and mathematical maturity would be absolutely essential. There would be no value whatever in a course in calculus that merely sets forth rules for calculation and formulas for solving certain types of problems without adequate attention to conceptual difficulties.

At Ohio University several department heads of colleges in which a large number of students having calculus in high school had this to say about it.

My experience has been that freshmen who have had a brief introduction to calculus often have a false sense of security that produces more troubles than might have developed if they had started from scratch.<sup>1</sup>

An introduction to calculus or less than an entire year series only tends to dull the students appetite for mathematical analysis.<sup>2</sup>

There are a great many textbooks available in modern mathematics. Some of these textbooks have made a radical change but most of them are based on a gradual change. A

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<sup>1</sup>Robert S. Brown, "Survey of Ohio College Opinions with Reference to High School Mathematics Programs", The Mathematics Teacher, LVI (April, 1963), p. 247.

<sup>2</sup>Ibid., p. 247.



school after setting up its objectives can usually find a textbook to use as a guide that will help meet the objectives of the school.

### Selecting the Students

The fourth step is the selection of students for the new program. It has been found that teachers do a better job and feel more comfortable the first time through the course with selected homogeneous groups of better than average ability. Many new programs are for college capable students and represent the top twenty-five per cent of the student body. After the teacher has gone through the course once, he can teach to any group of above average students. Most of these programs now are being used for the college-capable students. These programs have also been tried and have been used effectively with pupils of average or below average abilities.

One of the major defects of the traditional program for the seventh and eighth grade mathematics curricula now is that pupils of all abilities are required to give too much attention to so-called practical applications. Most junior high school pupils are not fascinated by such topics as taxation, banking, interest notes, installment buying and other applications of per cent. Emphasizing such topics not only fails to motivate the learning of mathematics but actually serves to reduce substantially the

amount of time that can be devoted to the development of new mathematical concepts. As a result, seventh and eighth grade mathematics has become largely a review of the arithmetic learned earlier with little or no advance in the pupils' understanding of mathematics. One of the great benefits of the modern mathematics program is that it stimulates interest and gives new understanding to a subject.

Judging from what the students in the new programs have accomplished so far, it is clear to many teachers that they have underestimated the mathematical power of the students, particularly in grades four through nine. Many excellent traditional mathematics teachers indicate that they have more difficulty changing to a new program than students do. It is not easy for teachers to change their way of looking at mathematics. Over a period of years they have built up certain reaction and language patterns when confronted with a mathematical problem. For many of these problems the new programs have changed the approach and language and in many cases the symbolism also. Since the student has not seen this material before, he sees nothing strange about it at all; teachers, however, are forced to unlearn or forget the old approach and learn the new one. The new programs are written in such a way that the student though does not have to unlearn anything when he gets into



an up-to-date college mathematics course.

### Informing the Parents

The fifth step in the process of implementation is informing parents about the new program. Many parents become uneasy when they can't do Johnny's homework; the transition will be much smoother if parents are informed about the aims of the new programs. Parents should be informed about the new methods of teaching mathematics at the time their children enter one of the new programs.

While there have been many popular articles written about the new mathematics programs, a discussion of the particular new program with parents will make them more sympathetic and will give them an understanding of the school's position if the new courses becomes difficult for some of the students. If parents have not been properly prepared they may blame the program for their child's difficulty. For example, the student with an excellent capacity for rote memory may find that "thinking out" for himself some of the newer concepts in mathematics requires more mental effort than he is willing to expend, and as a result his grades drop. The belief that rote-memory is short-lived, and in the end will net very little real mathematical learning that will be useful later on must be communicated to the parents.

### Informing Others in the School System

The sixth step is to inform other members of the school system about the new program and its implications for the mathematics curriculum, kindergarten through grade twelve. It is important that other departments in the school system be aware of the new mathematics program; such information will save them embarrassment when they are asked about it.

Each school system must also establish communication lines among all mathematics teachers, kindergarten through grade twelve, and all other people responsible for the mathematics curriculum, so that they can study the implications of the new program for all grades. Consider the old criticism of mathematics instruction. Senior high school teachers blamed junior high school teachers and junior high school teachers blamed elementary school teachers for passing inadequately prepared students to the next level. To eliminate such criticisms, a school must have coordinated kindergarten through grade twelve programs for each type of student. For most schools, in-service education courses should be set up to instruct teachers in the new mathematics they are supposed to teach and to show how it fits in with preceding and succeeding levels.



### Continuing Teacher Preparation

The seventh step is continuation of teacher preparation for carrying the new program to higher and lower grades. Experience has shown that school systems large enough should have at least two teachers in each building teaching the same new course. One needs to be able to talk over the problems that arise. In order to develop a precise language in mathematics one needs to practice it on fellow teachers who can point out ambiguous and imprecise statements. This precise language cannot be expected of the student until he has heard his teacher use it for a considerable period of time. Old habits and language are difficult to change; those who are used to the traditional language of mathematics need time to learn the new symbolism and make it part of them.

To support a new program each school system must acquire an adequate library of reference material for students and teachers. There is much new material that can be read independently by students, and it is necessary that they learn how to use the library in the study of mathematics. This type of training is very important in developing the ability of students to do independent work. The library is also very helpful to teachers, particularly while they are studying the new programs.

Some things administrators can do to help in the

in-service education of mathematics teachers are:

1. Encourage teachers to read and study books on modern mathematics.
2. Develop a co-operative in-service education program between the public school and a college or university in the area.
3. Provide the necessary funds to pay teachers to work on curriculum materials during the summer months.
4. Encourage teachers to visit classes in schools where the new materials in mathematics are being taught. Substitute teachers should be provided by the administration.
5. Set up salary schedules which provide appropriate increases for teachers who complete additional college courses in the subject matter of their teaching field.
6. Make provisions in the regular school budget for financing a continuous in-service education program.
7. Arrange the school schedule to allow teachers, on released time to participate in seminar curriculum study groups, professional organization meetings and teacher in-service programs.
8. Encourage local industrial organizations and philanthropic agencies to sponsor in-service education programs.
9. Encourage mathematics teachers to join their professional associations both in mathematics and in general education.
10. Assist teachers to develop professionally by encouraging them to take an active part in experimental mathematics programs.
11. Organize a mathematics curriculum study committee consisting of teachers from various grade levels. This would help to provide continuous development of the basic unifying concepts of mathematics.



12. Engage well qualified consultants to assist the local mathematics curriculum committee in their study of the present total school mathematics program.
13. Provide a teacher's reading and conference room with books on modern mathematics for developing new course material.
14. Encourage the development of appropriate correspondence courses in mathematics for teachers.<sup>1</sup>

#### Time and Compensation for Work on New Programs

The eighth and final step, provision for adequate time and compensation for carrying on a new program year after year. It must be made clear to the administration and the school board that a new program in mathematics will cost more for books and materials, and this increase must be budgeted so that money will be available.

Participating teachers need adequate time for study and preparation. The housekeeping and extra-curricular duties they must perform should be kept to a minimum. Some schools have eliminated study hall duty from the schedules of teachers in the new programs. More clerical help should be made available to relieve the teachers. Proper compensation should be provided. In some schools teachers are paid to write new curricula during the summer.

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<sup>1</sup>Kenneth E. Brown, "Improved Programs in Mathematics Require In-service Education", The Mathematics Teacher, LIV (February, 1961), pp. 88-89.

## SUMMARY AND CONCLUSIONS

Revision of the mathematics curriculum is necessary because the nation's need for mathematics has changed greatly during this century. This change is due to the tremendous advances made by research, automation, and the development of the computing machine. Some subjects that were taught in mathematics before are now obsolete. Traditional mathematics consisted of learning rules with little understanding of the subject. Every effort has to be exerted to insure that the mathematics education provided by our schools is adequate for the needs of our times. This will be done if we have a mathematics curriculum based on modern mathematics.

Many new programs and materials have been produced to meet this current need for revision of the mathematics curriculum but these materials and programs should be carefully studied before a program is decided upon. In planning a curriculum using modern mathematics all students should be considered. A school when deciding what form curricular revision should take, should base any proposals on the existing curriculum and changes should consist of modification, modernization, and improvement of the existing pattern. The point of view of modern mathematics should be used as a guide in determining the modifications to be made.



The first step in implementing a modern mathematics program in the secondary schools is recognition by school authorities of the need for a new mathematics program. But before any kind of a program can be considered there must be adequate preparation of the teachers who are to take part in this program. There are many programs available to use as a guide in planning a secondary school's mathematics curriculum. When a new program is chosen the parents and others in the school system should be informed of the program. The important thing is that schools recognize there exists a need for revision of the present mathematics curriculum and that they take steps to implement some kind of a modern mathematics program into their schools.

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IMPLEMENTING A MODERN MATHEMATICS PROGRAM  
IN THE SECONDARY SCHOOLS

by

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B. S., Kansas State University, 1961

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AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

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Many studies have reported that proper mathematical instruction in secondary schools is of utmost importance in the scientific and technical education of our young people, and that the present curriculum is badly adapted to the needs of our students. Many types of programs have been introduced to meet these shifting needs of science and technology and the different aspects of implementing a modern mathematics program in the secondary school were considered.

It was the purpose of this study (1) to show why curricular revision in mathematics is necessary; (2) to determine what form this revision should take; and (3) to present the steps in implementing a new program of modern mathematics in the secondary schools.

The method of carrying out this investigation of modernizing a mathematics curriculum was a review of all available literature regarding this topic. Study and consideration were given to reports concerning experimental research with modern mathematics curriculums rather than a review of commercial texts.

Revision of the mathematics curriculum is necessary because the nation's need for mathematics has changed greatly during this century. This change is due to the tremendous advances made by research, automation, and the development of the computing machine. Some subjects that

were taught in mathematics before are now obsolete. Traditional mathematics consisted of learning rules with little understanding of the subject. Every effort has to be exerted to insure that the mathematics education provided by our schools is adequate for the needs of our times. This will be done if we have a mathematics curriculum based on modern mathematics.

Many new programs and materials have been produced to meet this current need for revision of the mathematics curriculum but these materials and programs should be carefully studied before a program is decided upon. Some of the problems a school should consider when deciding what form curricular revision should take are: moderns versus traditionalists, mathematics versus general culture, pure mathematics versus applied mathematics, integration versus segregation, revolutionaries versus conservatives, and diversity versus unity. In planning a curriculum using modern mathematics all students should be considered. A school when deciding what form curricular revision should take, should base any proposals on the existing curriculum and changes should consist of modification, modernization, and improvement of the existing pattern. The point of view of modern mathematics should be used as a guide in determining the modifications to be made.

The first step in implementing a modern mathematics



program in the secondary schools is recognition by school authorities of the need for a new mathematics program. But before any kind of a program can be considered there must be adequate preparation of the teachers who are to take part in this program. There are many programs available to use as a guide in planning a secondary school's mathematics curriculum. When a new program is chosen the parents and others in the school system should be informed of the program. The important thing is that schools recognize there exists a need for revision of the present mathematics curriculum and that they take steps to implement some kind of a modern mathematics program in their schools.